(2007, pp. 1,533–1,536) characterize the decline of sea ice as a conflation of thermodynamic and dynamic processes: ''Thermodynamic processes involve changes in surface air temperature (SAT), radiative fluxes, and ocean conditions. Dynamic processes involve changes in ice circulation in response to winds and ocean currents.'' In the following paragraphs we discuss warming, changes in the atmosphere, and changes in oceanic circulation, followed by a synthesis. It is critically important that we understand the dynamic forces that govern all aspects of sea ice given the polar bear's almost exclusive reliance on this habitat.

**Air and Sea Temperatures**

Estimated rates of change in surface air temperature (SAT) over the Arctic Ocean over the past 100 or more years vary depending on the time period, season, and data source used (Serreze et al. 2007, pp. 1,533–1,536). Serreze et al. (2007, pp. 1,533–1,536) note that, although natural variability plays a large role in SAT variations, the overall pattern has been one of recent warming.

Polyakov et al. (2003) compiled SAT trends for the maritime Arctic for the period 1875 through 2000 (as measured by coastal land stations, drifting ice stations, and Russian North Pole stations) and found that, since 1875, the Arctic has warmed by 1.2 degrees Celsius (C), an average warming of 0.095 degree C per decade over the entire period, and an average warming of 0.05 ± 0.04 degree C per decade during the 20th century. The increases were greatest in winter and spring, and there were two relative maxima during the century (the late 1930s and the 1990s). The ACIA analyzed land-surface air temperature trends as recorded in the Global Historical Climatology Network (GHCN) database, and documented a statistically significant warming trend of 0.09 degree C per decade during the period 1900–2003 (ACIA 2005, p. 35). For periods since 1950, the rate of temperature increase in the marine Arctic documented in the GHCN (ACIA 2005, p. 35) is similar to the increase noted by Polyakov et al. (2003).

Rigor et al. (2000) documented positive trends in SAT for 1979 to 1997; the trends were greatest and most widespread in spring. Comiso (2006) analyzed data from the Advanced Very High Resolution Radiometer (AVHRR) for 1981 to 2005, and documented an overall warming trend of 0.54 ± 0.11 degrees C per decade over sea ice. Comiso noted that ''it is apparent that significant warming has been occurring in the Arctic but not uniformly from one region to another.'' The Serreze et al. (2007, pp. 1,533–1,536) assessment of data sets from the National Centers for Environmental Prediction and the National Center for Atmospheric Research indicated strong surface and low-level warming for the period 2000 to 2006 relative to 1979 to 1999, consistent with the observed sea ice losses.

Stroeve and Maslowski (2007) noted that anomalously high temperatures have been consistent throughout the Arctic since 2002. Further support for warming comes from studies indicating earlier onset of spring melt and lengthening of the melt season (e.g., Stroeve et al. 2006, pp. 367–374), and data that point to increased downward radiation toward the surface, which is linked to increased cloud cover and water vapor (Francis and Hunter 2006, cited in Serreze et al. 2007, pp. 1,533–1,536).

According to the IPCC AR4 (IPCC 2007, p. 36), 11 of 12 years from 1995 to 2006 (the exception being 1996) were among the 12 warmest years on record since 1850; 2005 and 1998 were the warmest two years in the instrumental global surface air temperature record since 1850. Surface temperatures in 1998 were enhanced by the major 1997–1998 El Niño but no such large-scale atmospheric anomaly was present in 2005. The IPCC AR4 concludes that the ''warming in the last 30 years is widespread over the globe, and is greatest at higher northern latitudes (IPCC 2007, p. 37).'' Further, the IPCC AR4 states that greatest warming has occurred in the northern hemisphere winter (December, January, February) and spring (March, April, May). Average Arctic temperatures have been increasing at almost twice the rate of the rest of the world in the past 100 years. However, Arctic temperatures are highly variable. A slightly longer Arctic warm period, almost as warm as the present, was observed from 1925 to 1945, but its geographical distribution appears to have been different from the recent warming since its extent was not global.

Finally, Comiso (2005, p. 43) determined that for each 1 degree C increase in surface temperature (global average) there is a corresponding decrease in perennial sea ice cover of about 1.48 million sq km (0.57 million sq mi).

**Changes in Atmospheric Circulation**

Links have also been established between sea ice loss and changes in sea ice circulation associated with the behavior of key atmospheric patterns, including the Arctic Oscillation (AO; also called the Northern Annular Mode (NAM)) (e.g., Thompson and Wallace 2000; Limpasuvan and Hartmann 2000) and the more regional, but closely related North Atlantic Oscillation (NAO; e.g., Hurrell 1995). First described in 1998 by atmospheric scientists David Thompson and John Wallace, the Arctic Oscillation is a measure of air-pressure and wind patterns in the Arctic. In the so-called ''positive phase'' (or high phase), air pressure over the Arctic is lower than normal and strong westerly winds occur in the upper atmosphere at high latitudes. In the so-called ''negative phase'' (or low phase), air pressure over the Arctic is higher than normal, and the westerly winds are weaker.

Rigor et al. (2002, cited in Stroeve and Maslowski 2007) showed that when the AO is positive in winter, altered wind patterns result in more offshore ice motion and ice divergence along the Siberian and Alaskan coastlines; this leads to the production of more extensive areas of thinner, first-year ice that requires less energy to melt. Rigor and Wallace (2004, cited in Deweaver 2007) suggested that the recent reduction in September ice extent is a delayed reaction to the export of multi-year ice during the high-AO winters of 1989 through 1995. They estimated that the recovery of sea ice to its normal extent should take between 10 and 15 years. However, Rigor and Wallace (2004) estimated that the combined winter and summer AO-indices can explain less than 20 percent of the variance in summer sea ice extent in the western Arctic Ocean where most of the recent reductions in sea ice cover have occurred. The notion that AO-related export of multi-year ice from the Arctic is the principal cause of observed declines in Arctic sea ice extent has been questioned by several authors, including Overland and Wang (2005), Comiso (2006), Stroeve and Maslowski (2007), Serreze et al. (2007, pp. 1,533–1,536), and Stroeve et al. (2008) who note that sea ice extent has not recovered despite the return of the AO to a more neutral state since the late 1990s. Overland and Wang (2005) noted that the return of the AO to a more neutral state was accompanied by southerly wind anomalies from 2000–2005 which contributed to reducing the ice cover over time and ''conditioning'' the Arctic for the extensive summer sea ice reduction in 2007 (J. Overland NOAA, pers. comm. to FWS, 2007). Maslanik et al. (2007) reached a similar conclusion that despite the return of the AO to a more neutral state, wind and ice transport patterns that favor reduced ice cover in the western and central Arctic continued to play a role in the loss of sea ice in those regions. Maslanik et al.